U.S. DEPARTMENT OF COMMERCE
National Technical Information Service

PB-270 605

Canyon Ferry Reservoir Broadwater and Lewis and Clark Counties, Montana

National Eutrophication Survey, Corvallis, Oreg

Prepared for

Corvallis Environmental Research Lab, Oreg

May 77

PB 270 605

U.S. ENVIRONMENTAL PROTECTION AGENCY
NATIONAL EUTROPHICATION SURVEY

WORKING PAPER SERIES

CORVALLIS ENVIRONMENTAL RESEARCH LABORATORY - CORVALLIS, OREGON
and
ENVIRONMENTAL MONITORING & SUPPORT LABORATORY - LAS VEGAS, NEVADA

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE

Report
on
Canyon Ferry Reservoir
Broadwater and Lewis & Clark Counties
Montana
EPA Region VIII
Working Paper No. 700

With the cooperation of the
Montana Department of Health & Environmental Sciences
and the
Montana National Guard
May, 1977

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO.	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE Report on Canyon Ferry Reservoir, Broadwater and Lewis & Clark Counties, Montana		5. REPORT DATE Prepared May 1977 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Anonymous (National Eutrophication Survey Staff)		8. PERFORMING ORGANIZATION REPORT NO. Working Paper # 790
9. PERFORMING ORGANIZATION NAME AND ADDRESS National Eutrophication Survey U.S. Environmental Protection Agency 200 S. W. 35th St. Corvallis, Oregon 97330		10. PROGRAM ELEMENT NO. 11. CONTRACT/GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS Office of Research and Development U.S. Environmental Protection Agency 401 M Street, S. W. Washington, DC 20460		13. TYPE OF REPORT AND PERIOD COVERED Final - 1976 14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

Prepared in cooperation with the U.S. Environmental Protection Agency, National Environmental Research Center, Las Vegas, Nevada 89114

16. ABSTRACT

Annual total phosphorus and total nitrogen loadings to the lake were estimated and subdivided according to either point or non-point source origin. An assessment of the lake's trophic condition and limiting nutrient is also provided. All data collected by the U.S.E.P.A. National Eutrophication Survey during the one year study of the lake and its tributaries are included in the report.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
eutrophication lakes nutrients phosphorus nitrogen loading		06B 08C

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS (This Report)	21. NO. OF PAGES
Release unlimited	20. SECURITY CLASS (This page)	22. PRICE

10

A04-A01

EPA Form 2220-1 (9-73)

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FOREWORD

The National Eutrophication Survey was initiated in 1972 in response to an Administration commitment to investigate the nation-wide threat of accelerated eutrophication to freshwater lakes and reservoirs.

OBJECTIVES

The Survey was designed to develop, in conjunction with state environmental agencies, information on nutrient sources, concentrations, and impact on selected freshwater lakes as a basis for formulating comprehensive and coordinated national, regional, and state management practices relating to point-source discharge reduction and non-point source pollution abatement in lake watersheds.

ANALYTIC APPROACH

The mathematical and statistical procedures selected for the Survey's eutrophication analysis are based on related concepts that:

a. A generalized representation or model relating sources, concentrations, and impacts can be constructed.

b. By applying measurements of relevant parameters associated with lake degradation, the generalized model can be transformed into an operational representation of a lake, it's drainage basin, and related nutrients.

c. With such a transformation, an assessment of the potential for eutrophication control can be made.

LAKE ANALYSIS

In this report, the first stage of evaluation of lake and watershed data collected from the study lake and its drainage basin is documented. The report is formatted to provide state environmental agencies with specific information for basin planning [§303(e)], water quality criteria/standards review [§303(c)], clean lakes [§314(a,b)], and water quality monitoring [§106 and §305(b)] activities mandated by the Federal Water Pollution Control Act Amendments of 1972.

Beyond the single lake analysis, broader based correlations between nutrient concentrations (and loading) and trophic condition are being made to advance the rationale and data base for refinement of nutrient water quality criteria for the Nation's fresh water lakes. Likewise, multivariate evaluations for the relationships between land use, nutrient export, and trophic condition, by lake class or use, are being developed to assist in the formulation of planning guidelines and policies by EPA and to augment plans implementation by the states.

ACKNOWLEDGEMENT

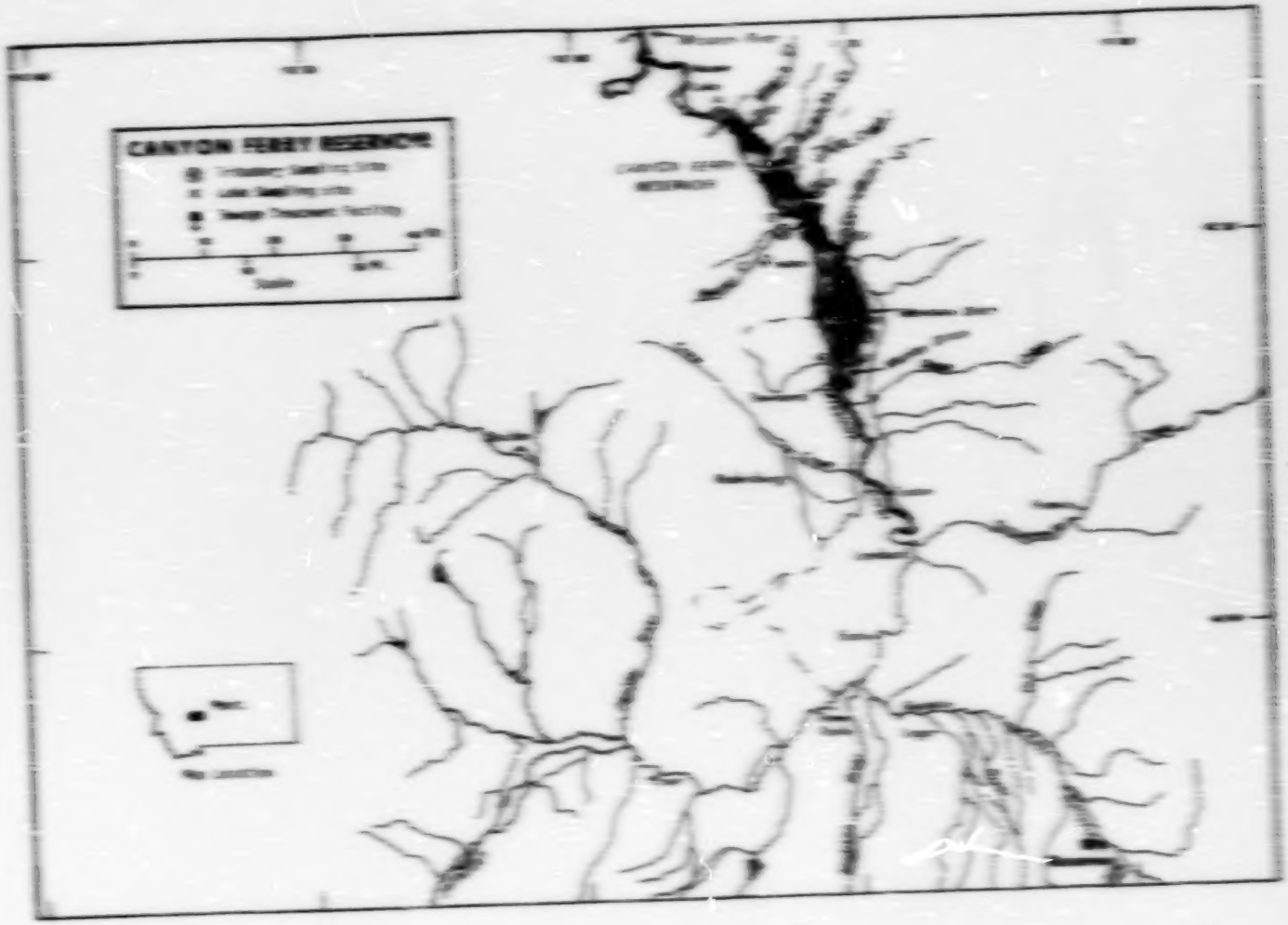
The staff of the National Eutrophication Survey (Office of Research & Development, U.S. Environmental Protection Agency) express sincere appreciation to the Montana Department of Health and Environmental Sciences for professional involvement, to the Montana National Guard for conducting the tributary sampling phase of the Survey, and to those Montana wastewater treatment plant operators who voluntarily provided effluent samples.

The staff of the Water Quality Bureau provided invaluable lake documentation and counsel during the Survey, reviewed the preliminary reports, and provided critiques most useful in the preparation of this Working Paper series.

Major General John J. Womack, the Adjutant General of Montana, and Project Officer Major William Yeager, who directed the volunteer efforts of the Montana National Guardsmen, are also gratefully acknowledged for their assistance to the Survey.

NATIONAL EUTROPHICATION SURVEY
STUDY LAKES AND RESERVOIRS
STATE OF MONTANA

LAKE NAME	COUNTY
Canyon Ferry	Broadwater, Lewis and Clark
Clark Canyon	Beaverhead
Flathead	Flathead, Lake
Georgetown	Deer Lodge, Granite
Hebgen	Gallatin
Koocanusa	Lincoln, MT; British Columbia, Can.
Mary Ronan	Lake
McDonald	Flathead
Nelson	Phillips
Seeley	Missoula
Swan	Lake
Tally	Flathead
Tiber	Liberty, Toole
Tongue River	Big Horn
Whitefish	Flathead
Yellowtail	Carbon, Bighorn, MT; Bighorn, WY


CANYON FERRY RESERVOIR

CANYON FERRY RESERVOIR

STORET NO. 3001

I. CONCLUSIONS

A. Trophic Condition:

Survey data indicate that Canyon Ferry Reservoir is eutrophic. It ranked last in overall trophic quality when the 15 Montana lakes and reservoirs sampled in 1975 were compared using a combination of six water quality parameters*. Twelve of the water bodies had less median total phosphorus, 13 had less median dissolved orthophosphorus, 12 had less median inorganic nitrogen, 11 had less mean chlorophyll a, and 11 had greater mean Secchi disc transparency. Depression of dissolved oxygen with depth occurred at stations 2 and 3 in July and at station 4 in September.

Survey limnologists noted a bloom of filamentous algae at stations 2, 3, 4, and 5 during the July sampling and submerged macrophytes at station 1 in September. The periodic dominance of blu -green algae in late summer has been noted in reports of limnological investigations of the reservoir (Wright, 1958; 1959; 1960; 1961; 1965).

B. Rate-Limiting Nutrient:

The algal assay results indicate that Canyon Ferry Reservoir was nitrogen limited at the times the samples were collected (09/04/75 and 10/22/75). The reservoir data indicate nitrogen limitation at all sampling stations and times except for station 1 in September.

* See Appendix A.

C. Nutrient Controllability:

1. Point sources--During the sampling year, point sources contributed less than 0.6% of the total phosphorus load to Canyon Ferry Reservoir. The wastewater treatment plant at Townsend contributed 0.4%, and septic tanks serving shoreline dwellings and campgrounds were estimated to have contributed less than 0.1%. In addition, a wastewater treatment plant of unknown significance at Bozeman was not included as a point source since it is beyond the 40-kilometer limit of the Survey* (see map, page v).

The present phosphorus loading of 2.27 g/m^2/year is twice that proposed by Vollenweider (Vollenweider and Dillon, 1974) as a eutrophic loading (see page 16). The phosphorus loadings of 2.05 g/m^2/yr and 2.44 g/m^2/yr, derived from the 1971 and 1972 phosphorus budgets prepared by Wright et al. (1974), support the Survey findings and indicate the need for nutrient control to establish a more persistent phosphorus-limited condition and slow the present rate of eutrophication of the reservoir.

2. Non-point sources--Non point sources contributed over 99% of the total phosphorus load during the sampling year. The Missouri River contributed 97.8%, Beaver Creek contributed 0.2%, and Confederate Creek contributed 0.1%. The ungaged minor tributaries and immediate drainage contributed an estimated 0.7%.

* See Working Paper No. 175, "...Survey Methods, 1973-1976".

As noted above, part of the phosphorus load in the Missouri River may be due to the Bozeman wastewater treatment plant effluent rather than non-point sources. In addition, irrigation in the drainage basin also may be significant. An additional study is needed to determine the contribution and significance of all point and non-point sources impacting the Missouri River and its tributaries upstream from the reservoir.

II. RESERVOIR AND DRAINAGE BASIN CHARACTERISTICS†

A. Morphometry††:

1. Surface area: 142.45 kilometers².
2. Mean depth: 17.4 meters.
3. Maximum depth: 50.6 meters.
4. Volume: 2,478,630 x 10^6 m^3.
5. Mean hydraulic retention time: 186 days.

B. Tributary and Outlet:
(See Appendix C for flow data)

1. Tributaries -

Name	Drainage area (km^2)*	Mean Flow (m^3/sec)*
Missouri River	39,730.4	150.450
Magpie Creek	63.4	0.105
Beaver Creek	148.7	0.222
Confederate Creek	149.2	0.440
Minor tributaries & immediate drainage -	949.2	4.276
Totals	41,040.9	155.493**

2. Outlet -

Missouri River	41,191.3***	153.840

C. Precipitation****:

1. Year of sampling: 44.7 centimeters.
2. Mean annual: 29.3 centimeters.

† Table of metric conversions--Appendix D.
†† Norpestad, 1975.
* For limits of accuracy, see Working Paper No. 175.
** Sum of inflows adjusted to equal outflow plus evaporation.
*** Includes area of reservoir.
**** See Working Paper No. 175.

III. WATER QUALITY SUMMARY

Canyon Ferry Reservoir was sampled four times during the open-water season of 1975 by means of a pontoon-equipped Huey helicopter. Each time, samples for physical and chemical parameters were collected from one or more depths at five stations on the reservoir (see map, page v). During each visit, a single depth-integrated (4.6 m or near bottom to surface) sample was composited from the stations for phytoplankton identification and enumeration; and during the September and October visits, a single 18.9-liter depth-integrated sample was composited for algal assays. Also each time, a depth-integrated sample was collected from each of the stations for chlorophyll a analysis. The maximum depths sampled were 1.5 meters at station 1, 13.7 meters at station 2, 24.1 meters at station 3, 34.4 meters at station 4, and 50.3 meters at station 5.

The sampling results are presented in full in Appendix D and are summarized in the following table.

A. SUMMARY OF PHYSICAL AND CHEMICAL CHARACTERISTICS FOR [illegible] RESERVOIR
STORET CODE [illegible]

	1ST SAMPLING ([illegible]) 5 SITES			2ND SAMPLING ([illegible]) 5 SITES			3RD SAMPLING ([illegible]) 5 SITES		
PARAMETER	RANGE	MEAN	MEDIAN	RANGE	MEAN	MEDIAN	RANGE	MEAN	MEDIAN
TEMP (C)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
DISS OXY (MG/L)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
CNDCTVY (MCROMO)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
PH (STAND UNITS)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TOT ALK (MG/L)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TOT P (MG/L)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
ORTHO P (MG/L)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
NO2+NO3 (MG/L)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
AMMONIA (MG/L)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
KJEL N (MG/L)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
INORG N (MG/L)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TOTAL N (MG/L)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
CHLRPYL A (UG/L)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
SECCHI (METERS)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

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B. Biological Characteristics:

1. Phytoplankton -

Sampling Date	Dominant Genera	Algal Units per ml
06/26/75	1. Chroomonas sp.	411
	2. Melosira sp.	376
	3. Fragilaria sp.	274
	4. Diatoma sp.	205
	5. Cymbella sp.	137
	Other genera	753
	Total	2,156
07/31/75	1. Fragilaria sp.	2,667
	2. Aphanizomenon sp.	1,731
	3. Nitzschia sp.	187
	4. Chroomonas sp.	187
	5. Synedra sp.	140
	Other genera	94
	Total	5,006
09/04/75	1. Fragilaria sp.	389
	2. Melosira sp.	389
	3. Chroomonas sp.	311
	4. Asterionella sp.	78
	5. Stephanodiscus sp.	39
	Other genera	116
	Total	1,322
10/22/75	1. Aphanizomenon sp.	265
	2. Chroomonas sp.	144
	3. Melosira sp.	120
	4. Navicula sp.	96
	5. Cymbella sp.	48
	Other genera	145
	Total	818

F. Chlorophyll a -

Sampling Date	Station Number	Chlorophyll a (ug/l)
05/28/75	1	9.5
	2	3.4
	3	3.0
	4	2.2
	5	7.5
07/31/75	1	3.3
	2	11.4
	3	9.5
	4	13.2
	5	8.6
09/04/75	1	-
	2	9.2
	3	6.4
	4	4.3
	5	2.0
10/22/75	1	4.9
	2	2.2
	3	1.2
	4	1.5
	5	1.3

G. Limiting Nutrient Study:

1. Autoclaved, filtered, and nutrient spiked -

a. September sample; stations 1 through 5 -

Spike (mg/l)	Ortho P Conc. (mg/l)	Inorganic N Conc. (mg/l)	Maximum yield (mg/l-dry wt.)
Control	0.025	0.195	5.2
0.050 P	0.075	0.195	5.1
0.050 P + 1.0 N	0.075	1.195	20.9
1.0 N	0.025	1.195	8.0

b. October sample; stations 1, 2, and 3 -

Spike (mg/l)	Ortho P Conc. (mg/l)	Inorganic N Conc. (mg/l)	Maximum yield (mg/l dry wt.)
Control	0.025	0.150	5.7
0.050 P	0.075	0.150	5.6
0.050 P + 1.0 N	0.075	1.150	25.5
1.0 N	0.025	1.150	8.4

c. October sample; stations 4 and 5 -

Spike (mg/l)	Ortho P Conc. (mg/l)	Inorganic N Conc. (mg/l)	Maximum yield (mg/l dry wt.)
Control	0.035	0.182	7.4
0.050 P	0.085	0.182	6.5
0.050 P + 1.0 N	0.085	1.182	25.9
1.0 N	0.035	1.182	16.3

2. Discussion -

The control yields of the assay alga, Selenastrum capricornutum, indicate that the potential primary productivity of Canyon Ferry Reservoir was relatively high at the times the samples were collected (09/04/75 and 10/22/75). Also, in all three assays, the lack of growth response with the addition of phosphorus alone until nitrogen was also added indicates that the reservoir was limited by nitrogen at those times. Note that the addition of nitrogen alone resulted in yields significantly greater than those of the controls in all assays.

The reservoir data indicate nitrogen limitation at all stations with the exception of station 1 in September; i.e., the mean inorganic nitrogen/orthophosphorus ratios were 12/1

or less and nitrogen limitation would be expected. However, the September N/P ratio at station 1 was 15/1, and phosphorus limitation would be expected there.

Nitrogen limitation, as indicated by the algal assay or by in-reservoir nitrogen to phosphorus ratios, does not necessarily mean that the trophic condition of the reservoir can be improved by controlling nitrogen inputs. In many cases, the apparent condition of nitrogen-limitation results from excessive phosphorus input from point sources and is often accompanied by a corresponding increase in primary production. In such cases, the reversal of the enriched condition depends upon phosphorus control, not nitrogen control.

IV. NUTRIENT LOADINGS
(See Appendix E for data)

For the determination of nutrient loadings, the Montana National Guard collected monthly near-surface grab samples from each of the tributary sites indicated on the map (page v). Sampling was begun in October, 1974, and was completed in September, 1975.

Through an interagency agreement, stream flow estimates for the year of sampling and a "normalized" or average year were provided by the Montana District Office of the U.S. Geological Survey for the tributary sites nearest the reservoir.

In this report, nutrient loads for sampled tributaries were determined by using a modification of a U.S. Geological Survey computer program for calculating stream loadings*. Nutrient loads shown are those measured minus point-source loads, if any.

Nutrient loads for unsampled "minor tributaries and immediate drainage" ("ZZ" of U.S.G.S.) were estimated using the means of the nutrient loads, in $kg/km^2/year$, at stations B-1, E-1, and G-1 and multiplying the means by the ZZ area in km^2.

The operator of the Townsend wastewater treatment plant provided monthly effluent samples and corresponding flow data.

* See Working Paper No. 175.

A. Waste Sources:

1. Known municipal* -

Name	Pop. Served	Treatment	Mean Flow (m^3/d)	Receiving Water
Townsend	1,300	stab. pond	4,294.3	Missouri River

2. Known industrial - None

* Treatment plant questionnaire.

B. Annual Total Phosphorus Loading - Average Year:

1. Inputs -

Source	kg P/ yr	% of total
a. Tributaries (non-point load) -		
Missouri River	322,140	97.8
Magpie Creek	85	<0.1
Beaver Creek	675	0.2
Confederate Creek	370	0.1
b. Minor tributaries & immediate drainage (non-point load) -	2,185	0.7
c. Known municipal STP's -		
Townsend	1,305	0.4
d. Septic tanks* -	105	<0.1
e. Known industrial - None	-	-
f. Direct precipitation** -	2,495	0.8
Total	329,310	100.0

2. Outputs -

Reservoir outlet - Missouri River 183,030

3. Net annual P accumulation - 146,280, kg.

* Estimate based on 89 seasonal and 159 permanent shoreline residences and 1 campground; see Working Paper No. 175.
** See Working Paper No. 175.

C. Annual Total Nitrogen Loading - Average Year:

1. Inputs -

Source	kg N/yr	% of total
a. Tributaries (non-point load) -		
Missouri River	3,970,710	94.9
Magpie Creek	1,370	<0.1
Beaver Creek	4,090	0.1
Confederate Creek	9,825	0.2
b. Minor tributaries & immediate drainage (non-point load) -	36,730	0.9
c. Known municipal STP's -		
Townsend	4,485	0.1
d. Septic tanks* -	3,000	0.1
e. Known industrial - None	-	-
f. Direct precipitation** -	153,790	3.7
Total	4,186,900	100.0

2. Outputs -

Reservoir outlet - Missouri River 3,857,600

3. Net annual N accumulation - 329,400 kg.

D. Non-point Nutrient Export by Subdrainage Area:

Tributary	kg P/km²/yr	kg N/km²/yr
Missouri River	8	100
Magpie Creek	1	22
Beaver Creek	4	28
Confederate Creek	2	66

* Estimate based on 89 seasonal and 169 permanent shoreline residences and 1 campground; see Working Paper No. 175.
** See Working Paper No. 175.

E. Mean Nutrient Concentrations in Ungaged Streams:

Tributary	Mean Total P Conc. (mg/l)	Mean Total N Conc. (mg/l)
Avalanche Creek	0.086	0.650
White Creek	0.650	0.330
Manley Ditch*	0.240	0.715

F. Yearly Loads:

In the following table, the existing phosphorus loadings are compared to those proposed by Vollenweider (Vollenweider and Dillon, 1974). Essentially, his "dangerous" loading is one at which the receiving water would become eutrophic or remain eutrophic; his "permissible" loading is that which would result in the receiving water remaining oligotrophic or becoming oligotrophic if morphometry permitted. A mesotrophic loading would be considered one between "dangerous" and "permissible".

Note that Vollenweider's model may not be applicable to water bodies with short hydraulic retention times.

	Total Phosphorus		Total Nitrogen	
	Total	Accumulated	Total	Accumulated
grams/m²/yr	2.27	1.03	20.4	2.3

Vollenweider phosphorus loadings ($g/m^2/yr$) based on mean depth and mean hydraulic retention time of Canyon Ferry Reservoir:

"Dangerous" (eutrophic loading)	1.12
"Permissible" (oligotrophic loading)	0.56

* Only two samples.

V. LITERATURE REVIEWED

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VI. APPENDICES

APPENDIX A

LAKE RANKINGS

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[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

LAKES RANKED BY INDEX VAL.

[illegible]	LAKE CODE	LAKE NAME	INDEX VAL
1	[illegible]	[illegible]	[illegible]
2	[illegible]	[illegible]	[illegible]
3	[illegible]	[illegible]	[illegible]
4	[illegible]	[illegible]	[illegible]
5	[illegible]	[illegible]	[illegible]
6	[illegible]	[illegible]	[illegible]
7	[illegible]	[illegible]	[illegible]
8	[illegible]	[illegible]	[illegible]
9	[illegible]	[illegible]	[illegible]
10	[illegible]	[illegible]	[illegible]
11	[illegible]	[illegible]	[illegible]
12	[illegible]	[illegible]	[illegible]
13	[illegible]	[illegible]	[illegible]
14	[illegible]	[illegible]	[illegible]
15	[illegible]	[illegible]	[illegible]

APPENDIX B

CONVERSION FACTORS

CONVERSION FACTORS

Hectares x 2.471 = acres

Kilometers x 0.6214 = miles

Meters x 3.281 = feet

Cubic meters x 8.107 x 10^{-4} = acre/feet

Square kilometers x 0.3861 = square miles

Cubic meters/sec x 35.315 = cubic feet/sec

Centimeters x 0.3937 = inches

Kilograms x 2.205 = pounds

Kilograms/square kilometer x 5.711 = lbs/square mile

APPENDIX C

TRIBUTARY FLOW DATA

24

APPENDIX D

PHYSICAL and CHEMICAL DATA

APPENDIX F

TRIBUTARY AND WASTEWATER TREATMENT PLANT DATA

[illegible]

[redacted]

DATE	TIME	DEPTH	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
FROM	TO	OF	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
TO	AM	FEET	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

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